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13. ABSTRACT (Maximum 200 words)

Global-local design of large structures presents a great challenge to structural designers to coordinate the optimization of major structural components (wing or fuselage) with optimization of individual panel details. Moreover, the continuity of the adjacent designs in terms of their geometric and material variables presents a serious manufacturing difficulty for the large structure. The research developed methodology, computational infrastructure and algorithms with sound theoretical basis to extend industrial ad hoc approaches to the global-local design and blending of local designs. We proposed a two-level optimization approach employing genetic algorithms tailored to panel design on the lower level. Genetic algorithms involving both continuous and discrete design variables were developed for the design of composite structures. Response surface approximations to optimized panel failure loads are then used for the upper level wing or fuselage optimization. In addition, metrics for measuring continuity between adjacent panels were developed and incorporated in the optimization procedure.

14. SUBJECT TERMS
Two-level optimization, genetic algorithms, design of composite structures.

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Innovative Local-Global Methods for Aircraft Structural Design

Final Report

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Objectives

Global-local design of large structures with complex geometry presents a great challenge to structural designers. In particular, coordination between codes that optimize the structure or major structural components (such as entire wing or fuselage structures) and codes that optimize individual panel details requires substantial and careful effort to reach optimal or near optimal solutions. Moreover, the continuity of the adjacent designs (or the lack of it) in terms of their geometric and material variables presents a serious manufacturing difficulty for the large structure. The objective of the research was to develop methodology, computational infrastructure and algorithms with sound theoretical basis to extend industrial ad hoc approaches to the global-local design and blending of local designs. We proposed a two-level optimization approach employing genetic algorithms tailored to panel design on the lower level. Response

surface approximations to optimized panel failure loads are then used for the upper level wing or fuselage optimization. In addition, the problem of improving continuity between adjacent panels was investigated.

Key Research accomplishments

The research was conducted in close collaboration with Professor Layne Watson and Zafer Gürdal of Virginia Tech. The details of the research results are available in the publications. Here we summarize the key research accomplishments:

- Development of genetic algorithms (GAs) involving both continuous and discrete design variables for the design of composite structures.
- Development of a rigorous minimum-margin decomposition approach that allows performing the search for the global optimization in low-dimensional spaces.
- Use of response surface approximations to optimal surfaces in global/local optimal design
- Development of continuity metrics for adjacent composite panels
- Incorporation of the continuity metrics in the global and local level of composite structural design.

Personnel Supported

Faculty supported by the grant are R. T. Haftka. Graduate students include Boyang Liu and Laurent Grosset.

Visiting Scholars associated with the grant include Professor Akira Todoroki of the Tokyo Institute of Technology, Professor Mehmet Akgün of Middle Eastern Technical University in Turkey, and Professor Alfred van Keulen of the University of Delft in Holland.

Publications

Journal articles published during the grant period are:

McMahon, M.T., Watson, L.T., Soremekun, G.A., Gürdal, Z., and Haftka, R.T., ``A Fortran 90 Genetic Algorithm Module for Composite Laminate Structure Design," Engineering with Computers, 14, pp. 260-273, 1998.

Liu,B. Haftka R.T., Akgün M. and Todoroki, A., "Permutation Genetic Algorithm For Stacking Sequence Design Of Composite Laminates ", Computer Methods in Applied Mechanics and Engineering, 186, pp. 357-372, 2000.

Liu, B., Haftka, R.T., and Akgün M., "Two-Level Composite Wing Structural Optimization Using Response Surfaces," Structural and Multidisciplinary Optimization, 20/2, pp. 87-96, 2000.

Soremekun,G., Gürdal, Z., Haftka, R.T., and Watson, L.T., ``Composite laminate design optimization by genetic algorithm with generalized elitist selection," Computers & Structures 79(2), pp. 131-143, 2001.

Refereed conference papers published during the grant period are:

Liu, B., Haftka, R.T. and Akgün, M. A. "Composite Wing Structural Optimization Using Genetic Algorithms and Response Surfaces" Proceedings of the 7th AIAA/USAF/NASA /ISSMO Symposium on Multidisciplinary Analysis and Optimization, St. Louis, Missouri, September 2-4, 1998, Paper No. 98-4854.

Liu, B., Haftka, R.T., and Akgün, M. A, " Composite Wing Structural Optimization By Genetic Algorithms, Response Surfaces, and Rounding ", Proceeding of 3rd World Congress of Structural and Multidisciplinary Optimization, Buffalo, New York, May 17-21, 1999, pp. 266-268.

Liu, B., Haftka, R.T., and Akgün, M. A, "Two-Level Composite Wing Structural Optimization Using Response Surfaces ", Proceeding of First ASMO UK / ISSMO conference on Engineering Design Optimization, Ilkley, West Yorkshire, UK, July 8-9, 1999, pp. 19-27.

Van Keulen, F., Liu, B., and Haftka, R.T., "Noise and Discontinuity Issues in Response Surfaces Based on Functions and Derivatives,", Proceedings, 41th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, Atlanta, Georgia, April 3-6, 2000. AIAA Paper 2000-1363

Liu, B., and Haftka, R.T., " Composite Wing Structural Design Optimization with Continuity Constraints," Proceedings, AIAA/ASME/ASCE/AHS/ASC 42nd Structures, Structural Dynamics, and Material Conference, Seattle, Washington, April 16-18, 2001.

Liu, B., and Haftka, R.T., " Maximization of Continuity of Complex Composite Structures by Permutation Genetic Algorithms," Proceedings 4rd World Congress of Structural and Multidisciplinary Optimization, Dalian China, June 4-8, 2001.

Technology Transfer/Interactions

The global/local design approach developed under the grant is currently being evaluated by Vanderplaats Research and Development and the Visteon corporation for design of large composite automotive structures. The algorithms developed will be demonstrated for incorporation in the GENESIS commercial structural optimization software.

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RESULT
Collaborating on application of global-local approach
APPLICATION
Optimal design of automotive structures for increased structural efficiency

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RESULT
Collaborating on application of global-local approach
APPLICATION
Optimization of composite laminates in GENESIS software

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RESULT
Demonstrated application of response surface technology to automotive problems
APPLICATION
Optimal design of automotive structures for increased fatigue life